Natural analogues and scenario development for use in repository safety and performance assessments

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Natural and anthropogenic analogues are well established in national and international studies related to the deep geological disposal of radioactive waste materials. One of the several advantages of analogues is that many features, events and processes which are expected to influence the safety and performance of a repository can be studied over timescales comparable to the expected lifespan of the repository. Much analogue data now exist but their direct use in safety and performance assessment modelling has been limited due to the complexity of natural systems and therefore the difficulty of establishing the physical and chemical boundary conditions necessary to model important processes and mechanisms. Consequently, emphasis has been put on ‘confidence building’ and ‘public perception’ issues. Increasingly, however, analogue studies are being integrated with laboratory and *in-situ* experiments to provide data which are more quantitative and directly applicable. Further to this approach is the application of analogues to the development of scenarios which provide the building blocks to safety and performance assessments. Two scenarios have been selected for general discussion: a) the Glacial Scenario in relation to northern hemisphere disposal sites, and b) a near-field/far-field interface scenario emphasising ion exchange and radionuclide sorption processes in clay environments.

Thermodynamic modelling of melting in chemically heterogenous mixtures of peridotite and pyroxenite.

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Melting of pyroxenite veins or layers has been proposed as an explanation for the ‘garnet signature’ in MORB and for characteristic source signatures in OIB. Recent experiments have constrained the melt productivity of respresentative pyroxenite compositions but pyroxenite melting in the convecting mantle will be enhanced by heat transfer from the surrounding peridotite. The algorithm DUAL_ADIABAT is based on the MELTS software package. It calculates isentropic decompression paths for two lithologies that are in thermal but not chemical equilibrium. We have used DUAL_ADIABAT to compare the melting of variable proportions of pyroxenite and peridotite along typical mantle adiabats with and without chemical equilibrium between the systems. The effects of melt extraction, homogenisation and transport processes and melt-region geometry may be tested.

At degrees of melting high enough to limit the influence of minor components, equal melt fraction contours calculated for a variety of pyroxenite compositions are consistently steeper in T-P space than those calculated for peridotites. This suggests that only the most silica-rich pyroxenites are liable to contribute to deep melting at plume-like mantle potential temperatures and that the melts will be diluted by melts from the peridotite.

Calculated batch melt compositions generated by melting of fertile mantle along a normal mantle adiabat and the corresponding residue compositions have been used to model pyroxenite and depleted mantle. This is more self-consistent than using experimentally investigated pyroxenites. The pyroxenites generated with peridotite melt fractions, F_p, of 0.1 – 0.3 span a range of ‘silica excess’ and ‘silica-deficient’ compositions. The factor by which pyroxenite productivity is increased by peridotite heat input is largest for the most silica-deficient pyroxenites. The depth of onset of melting in the peridotite decreases as the proportion of pyroxenite is increased. For batch melting of the pyroxenite this pressure correponds to the point where the isentropic P-T path of the pyroxenite / peridotite mixture crosses that of a chemically homogenous peridotite of the same bulk composition. In this case melting in the pyroxenite ceases once peridotite melting commences. If the proportion of pyroxenite is greater than or equal to F_p then the pyroxenite is completely molten at this point. Fractional melting of pyroxenite veins may continue once the peridotite begins to melt with reduced productivity.

Similar calculations for mixtures of fertile mantle and pyroxenites show comparable effects on melt productivity. The results place important constraints on the extent to which melting of pyroxenite veins can influence the chemical signature of MORB and OIB.